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(54) **Detector for distinguishing between smoke and other suspended particles**

(57) Smoke detecting apparatus comprises a lamp (10) transmitting a multi-wavelength light beam (12) across a space (14) in which smoke and other aerosols may be present. At beam detecting means (18), the received beam is split by a beam splitter (26) and passed to photo-diodes (22,24) through respective filters (28,30) having a narrow passbands centred at 0.5 and 0.9 micrometres. The respective output signals are amplified by amplifiers (32,34) and the ratio of the two output signals is measured in a processing unit (36). For smoke there is greater attenuation at 0.5 micrometres than at 0.9 micrometres, and the measured ratio therefore falls significantly. In the presence of other aerosols such as water vapour or dust, the wavelength dependence of the attenuating (scattering) effect on the beam is less strong or substantially non-existent. The output of the ratio unit (36) therefore discriminates in favour of smoke and against other aerosols.

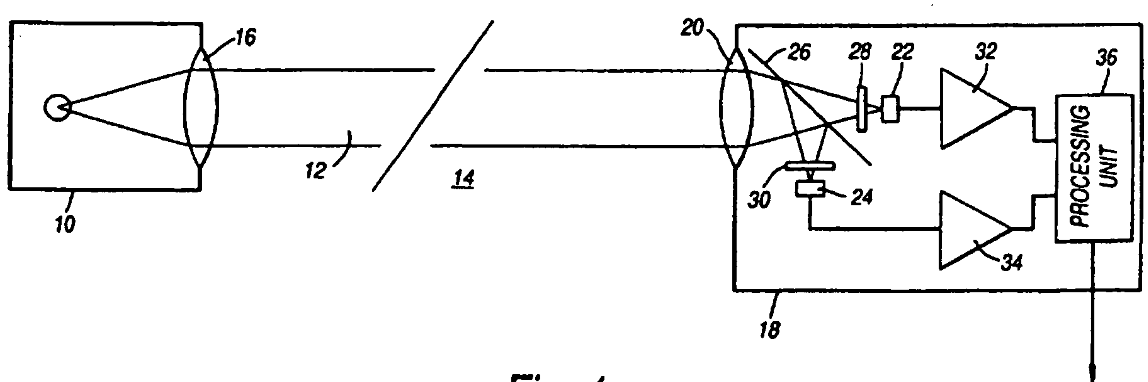

Fig. 1

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At least one drawing originally filed was informal and the print reproduced here is taken from a later filed formal copy.

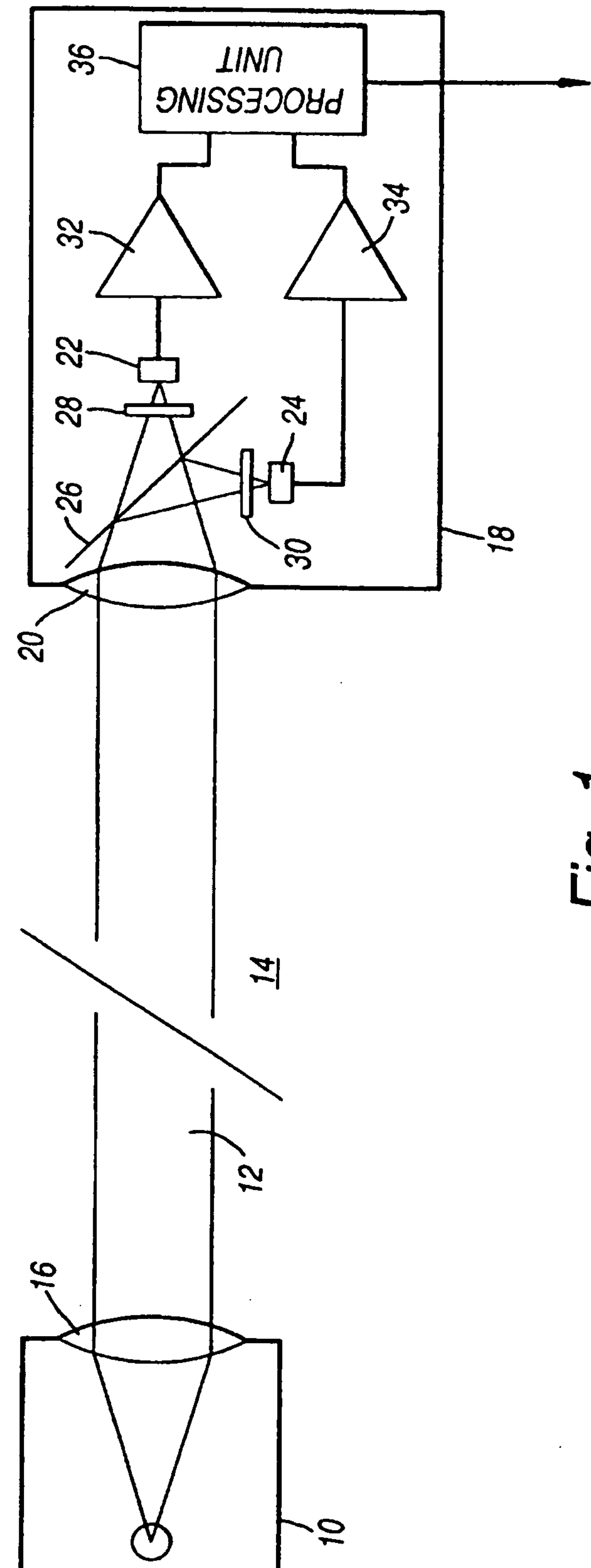
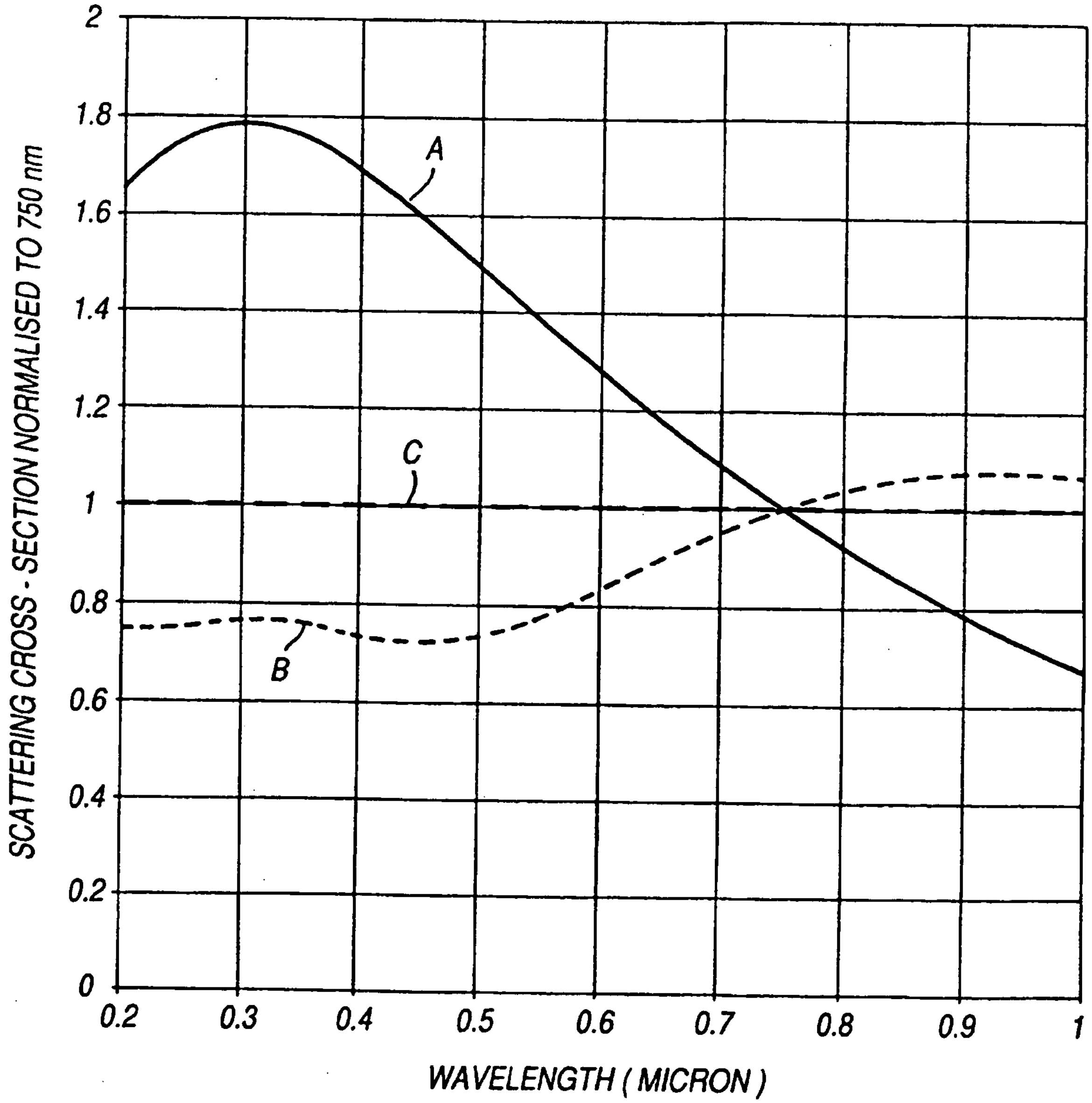


Fig. 1



SCATTERING CROSS - SECTION NORMALISED TO 750 nm
WAVELENGTH (MICRON)
A
B
C
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1

Fig. 2

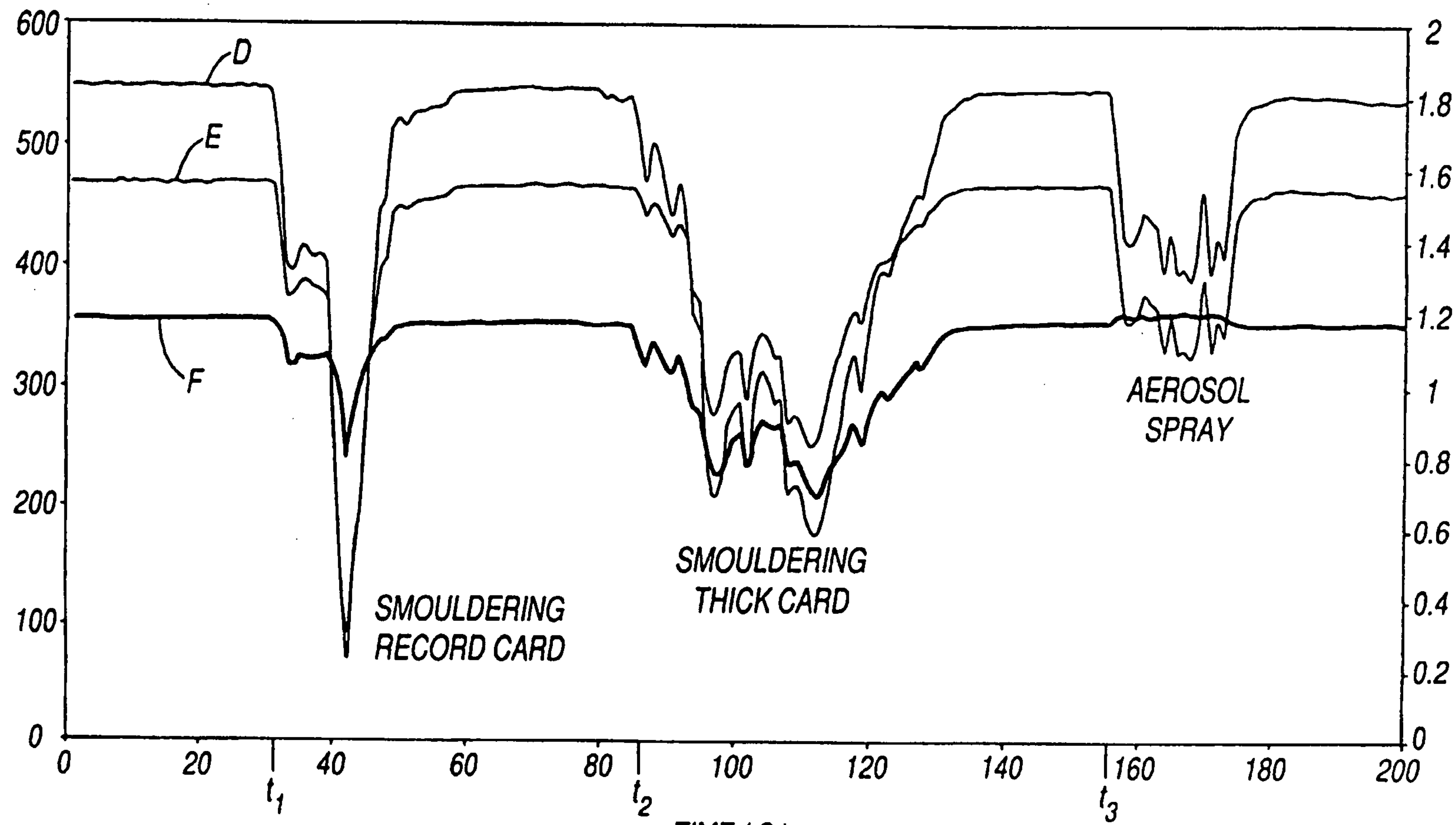

600
500
400
300
200
100
0
20
40
60
80
100
120
140
160
180
200
t_1
t_2
t_3
TIME (S)
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
RATIO
D
E
F
SMOULDERING
RECORD CARD
SMOULDERING
THICK CARD
AEROSOL
SPRAY

Fig. 3

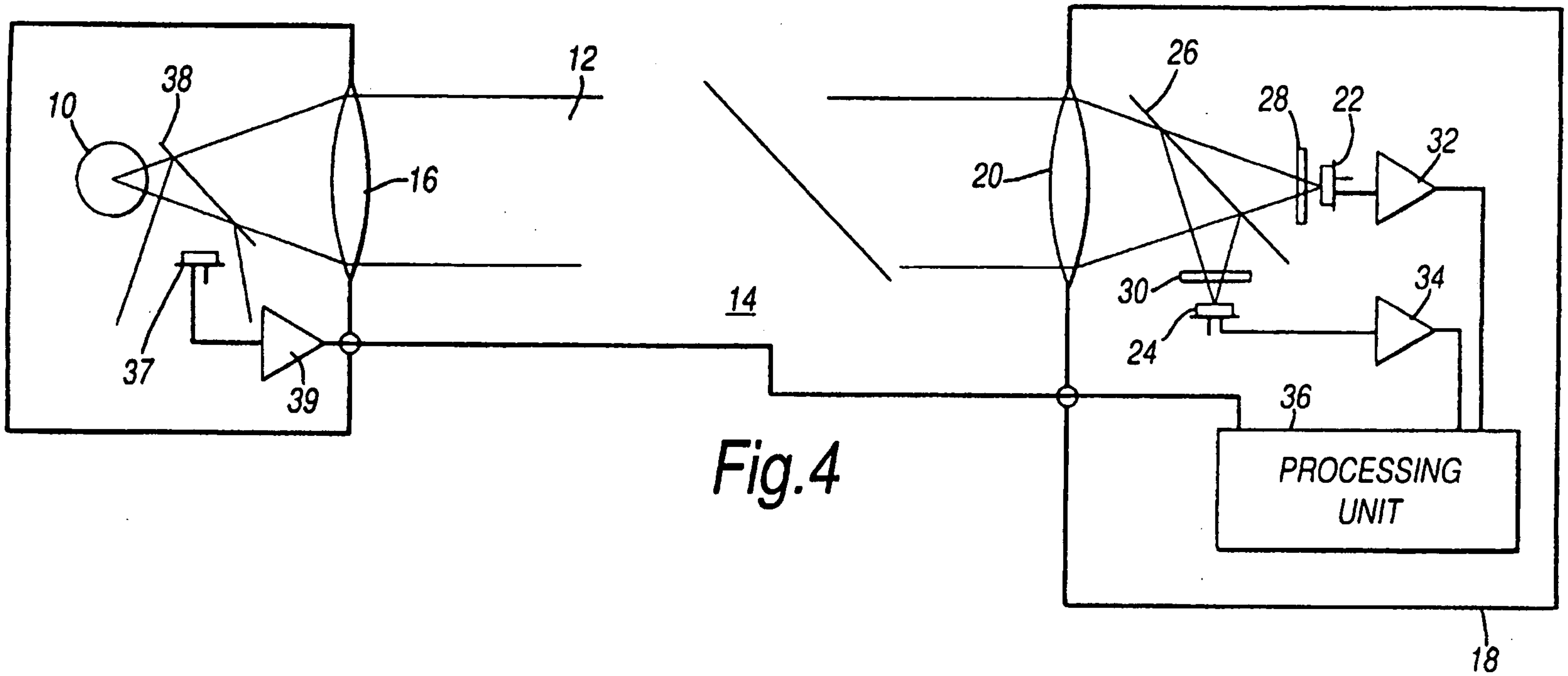

10
38
12
16
14
37
39
20
26
28
22
32
30
24
34
36
PROCESSING UNIT
18

Fig.4

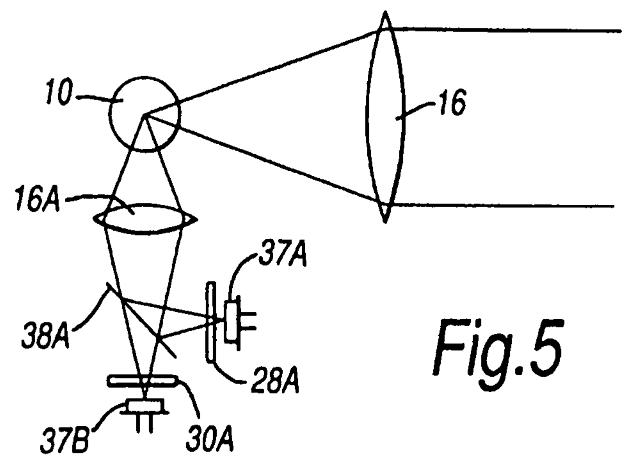

10
16
16A
37A
38A
28A
37B
30A

Fig.5

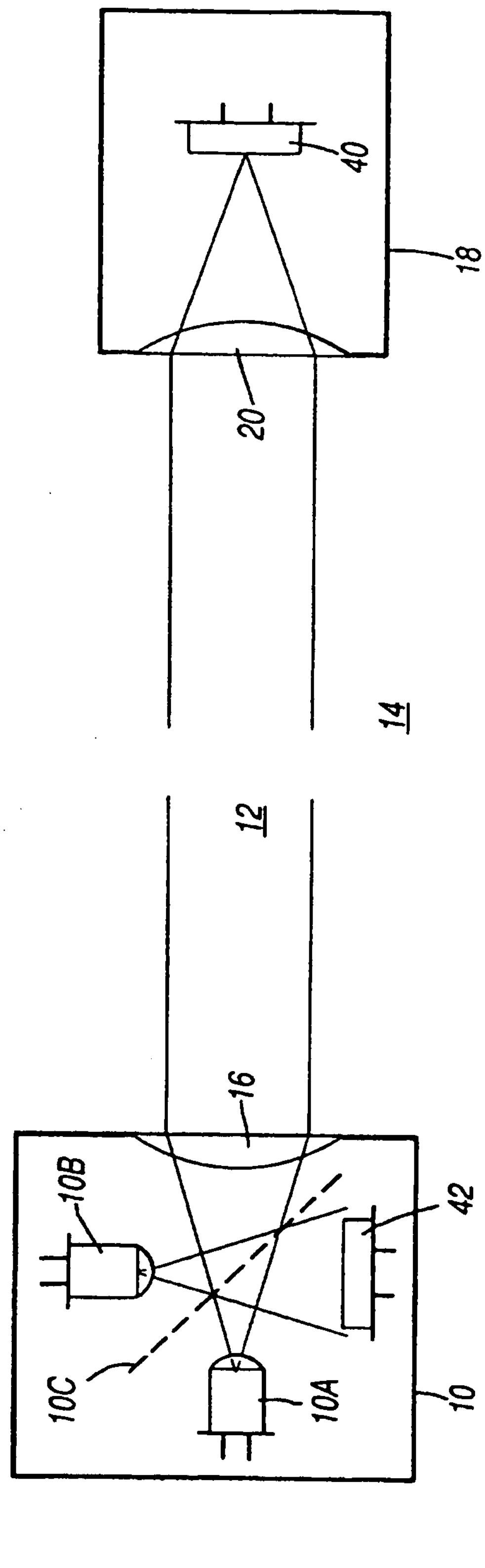
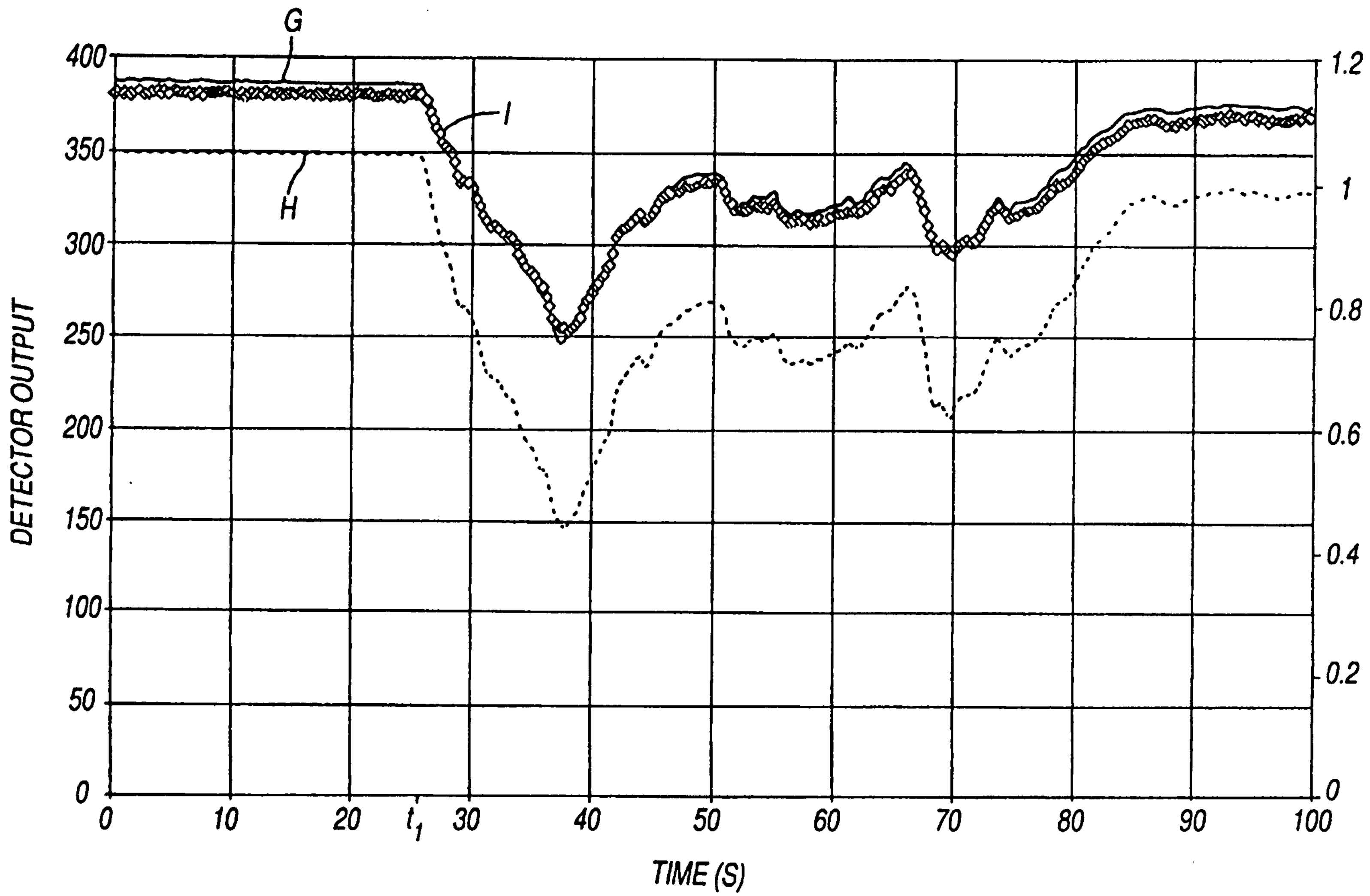


Fig.6



G
I
H
DETECTOR OUTPUT
400
350
300
250
200
150
100
50
0
RATIO
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
t_1
30
40
50
60
70
80
90
100
TIME (S)

Fig.7

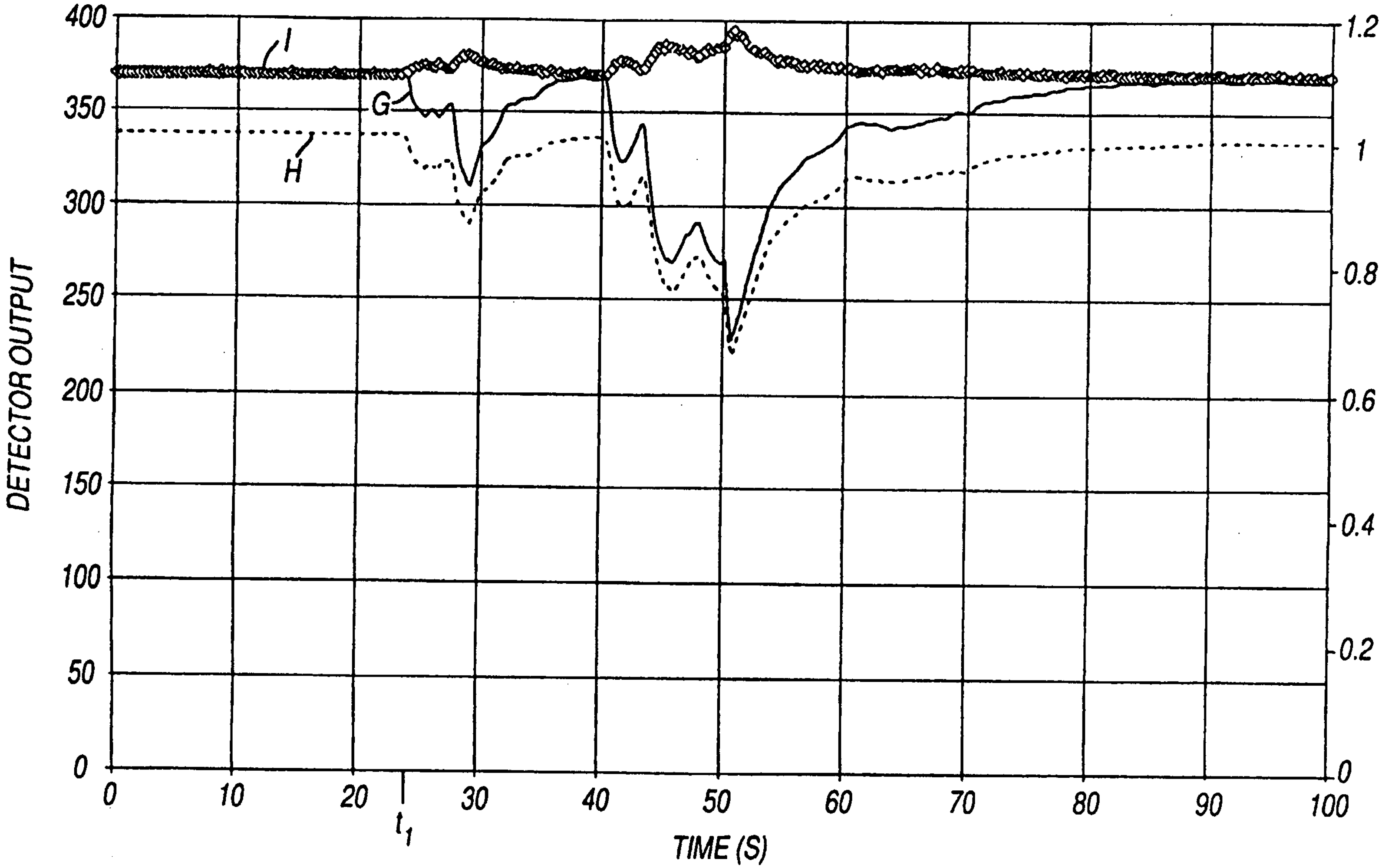

400
350
300
250
200
150
100
50
0
DETECTOR OUTPUT
1.2
1
0.8
0.6
0.4
0.2
0
RATIO
0
10
20
30
40
50
60
70
80
90
100
TIME (S)
t_1
I
G
H

Fig.8

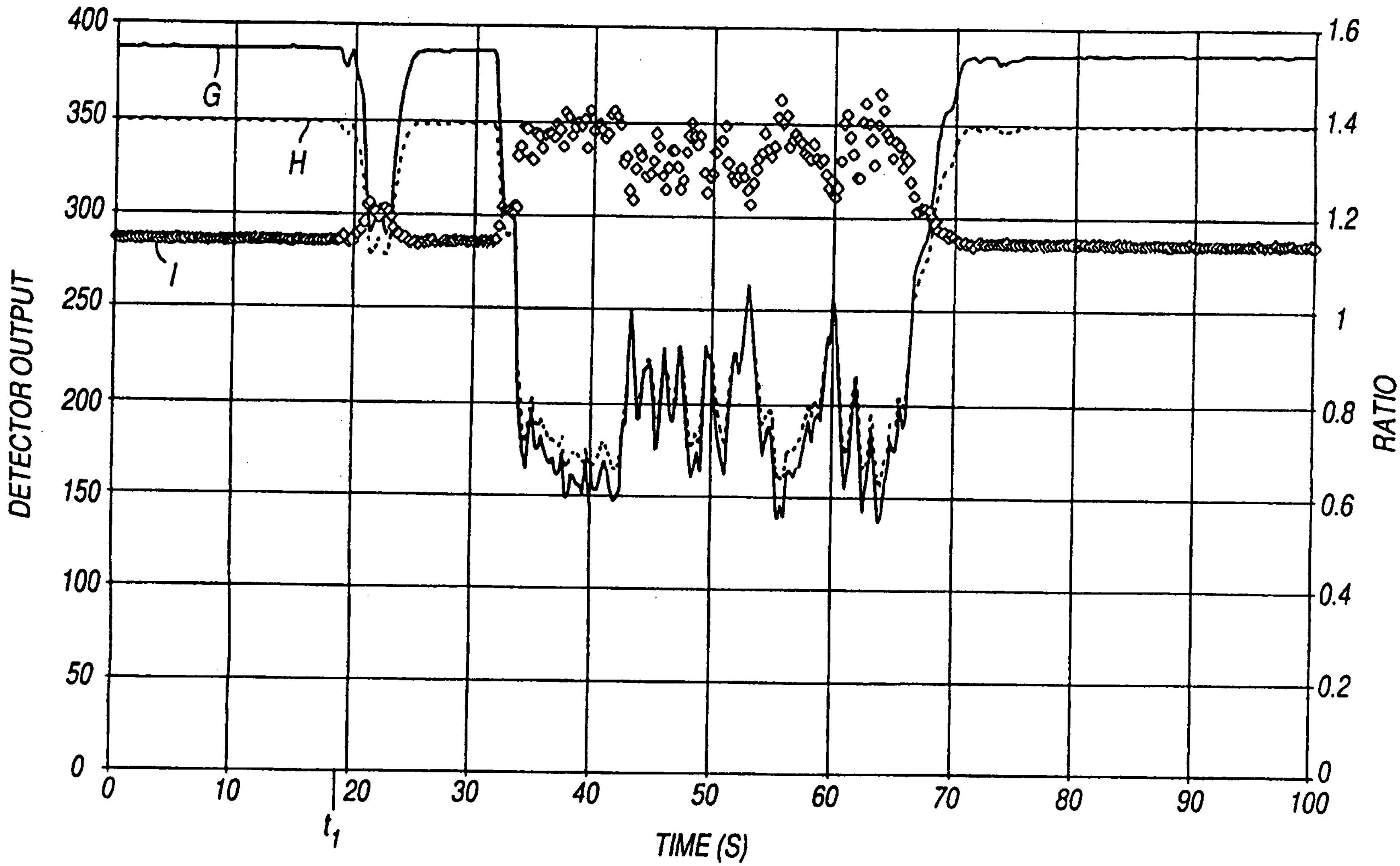

DETECTOR OUTPUT
RATIO
TIME (S)
G
H
I
t_1
400
350
300
250
200
150
100
50
0
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
10
20
30
40
50
60
70
80
90
100

Fig.9

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APPARATUS AND METHODS FOR SMOKE AND PARTICLE DETECTION

The invention relates to apparatus and methods for detecting smoke and atmospheric particulates.

According to the invention, there is provided particle detecting apparatus for detecting particles in suspension in a space and for distinguishing between particles of a first type and particles of a second type, comprising beam transmitting means for passing light at a plurality of different predetermined wavelengths through the space to detecting means operative to produce output signals respectively corresponding to the magnitude of the light received at the different wavelengths, the attenuation of the light caused by the presence of particles of the first type in the space being dependent on wavelength to a different extent from the attenuation of the light caused by the presence of particles of the second type in the space, whereby a comparison of the output signals from the detecting means enables detection of particles of the first type in preference to particles of the second type.

According to the invention, there is further provided smoke

detecting apparatus for detecting the presence of smoke in a space, comprising light transmitting means for transmitting light at at least a first and a second wavelength across the space to light detecting means, the light detecting means comprising first detecting means operative to detect variations in the magnitude of the light at the first wavelength to produce a first output signal and second detecting means operative to detect variations in the magnitude of the light received at the second wavelength so as to produce a second output signal, processing means operative to compare the two output signals, the first and second wavelengths being selected such that the effect of smoke in the space is to reduce one output signal substantially more than the other output signal and such that this effect does not occur, or does not occur to the same extent, in response to the presence of non-smoke particles in the space, reference means responsive to the light before it is transmitted across the space to produce a corresponding correction signal dependent on the effect on the light of drift in the light transmitting means, and means responsive to the correction signal for offsetting the effect of the drift on the comparison of the output signals from the detecting means.

According to the invention, there is also provided a method of

detecting particles in suspension in a space and for distinguishing between particles of a first type and particles of a second type, comprising the steps of passing light at a plurality of predetermined wavelengths through the space, detecting the received light to produce output signals respectively corresponding to the magnitude of the light received at the different wavelengths, the attenuation of the light caused by the presence of particles of the first type in the space being dependent on wavelength to a different extent from the attenuation of the light caused by the presence of particles of the second type in the space, comparing the output signals to enable detection of particles of the first type in preference to particles of the second type, detecting the light when it is unaffected by the said attenuation to produce a corresponding correction signal dependent on the effect of drift in the magnitude thereof, and using the correction signal to offset the effect of the drift on the comparison of the output signals.

Apparatus and methods according to the invention, for detecting smoke, will now be described, by way of example only, with reference to the accompanying diagrammatic drawings in which:

Figure 1 is a block diagram of one form of the apparatus;

Figure 2 is a graph for explaining the operation of the apparatus of Figure 1;

Figure 3 shows test results obtained by using apparatus of the form shown in Figure 1;

Figure 4 is a block diagram of a modified form of the apparatus of Figure 1; and

Figure 5 is a block diagram of part of the apparatus of Figure 4 showing a further modification;

Figure 6 is a block diagram of a further modified form of the apparatus of Figure 1; and

Figures 7,8 and 9 are diagrams for explaining the operation of the apparatus of Figure 6.

The apparatus and methods to be described are for use in protecting large volume enclosures from fire, by detecting the presence of smoke. The apparatus and methods involve the use of beam-type smoke detectors which project a beam of light (which term is used in this specification and its claims to include non-

visible electromagnetic radiation) across the enclosure, usually near its ceiling, to a detector. The presence of smoke within the enclosure, such as resulting from a fire, scatters the light from the projected beam and the signal received by the detector decreases, thereby enabling the smoke to be detected.

In the apparatus of Figure 1, a light source 10 projects a beam of light 12 across part of the enclosure 14 to be protected, the light being collimated by a collimating lens 16. The light source 10 may be an incandescent lamp.

The light beam 12 is received by a detecting unit 18, via a lens 20 which focusses the received light onto two detectors 22 and 24, such as photo-diodes, the light being directed to each of the detectors 22,24 by means of a beam splitter 26. The light reaching each photo-diode 22,24 is filtered by a respective absorbing-type filter (e.g. a glass filter) 28,30. Filter 28 is arranged to pass light in a narrow pass-band centred at 0.5 micrometres, and filter 30 is arranged to pass light in a narrow pass-band centred at 0.9 micrometres. The signals from the two photo-diodes 22,24 are then amplified by respective amplifiers 32,34 and fed to a processing unit 36.

The operation of the apparatus of Figure 1 will now be described.

It can be shown from light scattering theory [*"The scattering of light and other electro-magnetic radiation" M. Kerkov, Academic Press, N.Y., (1969)]* that the amount of light transmitted through an aerosol cloud is dependent on the particle size, number density, refractive index and light wavelength. The "scattering cross-section" determines the amount of light transmitted through the aerosol cloud according to the Beer-Lambert equation:

$$I = I_o \exp(-N\sigma\chi)$$

where I_o = incident light intensity

N = number density of particles

σ = scattering cross-section of particles

χ = path length through scattering medium

Therefore, the greater the scattering cross-section, the more light is removed from the beam and the lower the transmitted signal intensity.

Figure 2 shows the variation of the scattering cross-section of different types of aerosol as a function of wavelength. Curve A relates to smoke and shows that much more light is scattered

at shorter wavelengths than at longer wavelengths. Curve B relates to water mist; the wavelength-dependence is much less strong and more light is scattered at longer wavelengths than at shorter wavelengths. For dust particles (curve C), the light scattering is wavelength-independent.

Figure 2 therefore shows that measurement of transmitted light at two (or more) wavelengths will enable a distinction to be made between the scattering or obscuring effect of smoke and the scattering or obscuring effect of certain other types of particle. The apparatus of Figure 1 enables this to be achieved.

Figure 3 shows (curve D) the output of amplifier 32 (that is, the output at 0.5 micrometres) plotted against time. Curve E similarly plots the output from amplifier 34 - that is, the output at 0.9 micrometres. The left hand vertical scale applies for curves D and E.

At time t_1, the smoke from a smouldering record card is introduced into the region 14 traversed by the beam 12. As shown, there is a rapid and substantial reduction in the amplitudes of the outputs of both amplifiers, but the output (curve D) from amplifier 32 is reduced by a greater amount than

the output from amplifier 34 (curve E).

At time t_2, the smoke from a smouldering thick card is introduced into the region 14 traversed by the beam 12. Again, there is a substantial reduction in the outputs from both amplifiers, and again the output from amplifier 32 (curve D) is reduced by a greater amount than the output from amplifier 34 (curve E).

At time t_3, however, an aerosol spray is sprayed across the beam. In this case, the outputs from both amplifiers 32,34 (curves D and E) are reduced by substantially the same amount.

Curve F plots the ratio of the output of amplifier 32 (at 0.5 micrometres) to the output from amplifier 34 (at 0.9 micrometres) - the right hand vertical scale applies. At time t_1, this ratio falls significantly because the output of amplifier 32 has fallen by more than the output of amplifier 34. The same applies at time t_2. At time t_3, however, the ratio output does not change significantly because the outputs from both amplifiers change by about the same amount; in fact, the ratio measurement increases slightly.

Therefore, if the processing unit 36 is programmed so as to

produce an alarm output only when a reduction in the ratio of the outputs from the amplifiers 32 and 34 is detected, this will discriminate against false alarms which might be created in the presence of aerosol sprays if a detector operating at only a single wavelength is used. Advantageously, the processing unit 36 is programmed to require both a reduction in the detected signal ratio and a reduction in the intensities at the two wavelengths before producing an alarm output.

Figure 4 shows a modified form of the apparatus of Figure 1, ikn which items similar to those in Figure 1 have the same reference numerals.

The apparatus of Figure 4 differs from the apparatus in Figure 1 in that it includes an additional detector 37 which is mounted adjacent to the light source 10 and receives some of the light emitted by the light source 10 via a beam splitter 38. The detector 37 thus receives light directly from the lamp 10 and this light is therefore of course not affected in any way by smoke or other obscuration in the enclosure 14. The output of detector 37 is amplified by an amplifier 39 and fed to the processing unit 36. Changes in the output of detector 37 are thus dependent on drift in the light output from the source 10

and can be used in the processor unit 36 to compensate for such light output changes.

Figure 5 shows a further modification in which there are two reference detectors 37A and 37B instead of the single reference detector 37 of Figure 4. Light from the source 10 is passed through a lens 16A and thence to the reference detectors 37A and 37B via a beam splitter 38A and through filters 28A and 30A. Filters 28A and 30A are respectively similar to filters 28 and 30, filter 28A being arranged to pass light in a narrow pass-band centred at 0.5 micrometres and filter 30A being arranged to pass light in a narrow pass-band centred at 0.9 micrometers. The outputs from the reference detectors 37A and 37B are amplified by respective amplifiers (not shown) and passed to the processing unit 36.

Reference detectors 37A and 37B receive light directly from the light source 10 - that is, the light which they receive is not affected by any obscuration in the enclosure 14. Reference detectors 37A and 37B therefore produce outputs which are respectively dependent on the light output of the source 10 in the two narrow passbands centred at 0.5 and 0.9 micrometres. As explained in connection with Figure 4, therefore, these outputs

can be used in the processing unit to compensate for changes in the light output of the source 10. The arrangement in Figure 4 compensates for general changes in the output of the source 10. However, the arrangement shown in Figure 5 can detect changes in the light output of the source 10 which affect the light in one pass-band in a manner different from any such effect in the other pass-band and can thus provide more accurate compensation for changes or drift in the light output.

Figure 6 shows another form of apparatus. In this form, a light transmitting unit 10 comprises two light-emitting diodes 10A and 10B. LED 10A produces light in the near infra-red region at about 900 nanometres. LED 10B produces blue light at about 450 nanometres. The outputs from both LEDs are combined by a beam splitter 10C, collimated by the collimating lens 16 and transmitted as a beam 12 across the enclosure 14 to the detecting unit 18. In the detecting unit 18, the collimating lens 20 focusses the light onto a photo-diode 40.

A second photo-diode 42 is provided in the light transmitting unit 10 and receives light from the LEDs 10A and 10B directly via the beam splitter 10C.

The LED's can be operated in either of two modes.

In one mode, the LED's are pulsed off and on by respective drive circuits (not shown) at different frequencies. Each detector 40,42 will produce outputs corresponding to the light received from both LEDs. These outputs are detected and amplified. Because the LEDs are driven at different frequencies, the output from photo-diode 40 can be separated into a first output signal (having a magnitude 40A) due to the light from LED 10A and a second output signal (having a magnitude 40B) due to the light output from LED 10B. Similarly, the output from photo-diode 42 can be separated into a first output signal having a magnitude 42A due to the light from LED 10A and a second output signal having a magnitude 42B due to the light output from LED 10B. In order to split the output of each photo-diode 40,42 into the two respective output signals, narrow-band or lock-in amplifiers can be used (not shown).

In an alternative method, the LEDs 10A,10B are driven alternately in short pulses and the output signals from the photo diodes 40,42 are measured and recorded synchronously with each drive pulse. In this way, again, output signals 40A,40B,42A and 42B are produced. This second method is advantageous if minimum

power consumption is important.

The four output signals 40A,40B,42A and 42B are processed in a processing unit 44 and the ratio R is produced, where

$$R = \frac{40B \times 42A}{40A \times 42B}$$

The ratio 42A/42B will be unaffected by any obscuration of the beam 12. However, the ratio 40B/40A corresponds to the ratio of the output of amplifier 32 to the output of amplifier 34 in the apparatus of Figure 1. As explained in connection with that Figure, this ratio will be reduced significantly in the presence of smoke but will be not or less reduced in the presence of other aerosols not to be detected. The inclusion of the ratio 42A/42B in R above provides compensation for drift in the output of the LEDs and in the detectors 40,42.

Figure 7 shows the response of the apparatus of Figure 6 in the presence of smoke from flaming plastic. The smoke begins to interfere with the beam at time t_1. Curve G represents the output signal 40A and curve H represents the output signal 40B, both measured on the left hand vertical axis. Curve I represents the ratio R, measured on the right hand vertical axis. Figure 7 shows that the two beams (at each of the two wavelengths) across the space 14 are both substantially affected by the

presence of smoke, resulting in a substantial fall in the ratio R.

Figure 8 shows the operation of the apparatus of Figure 6 when maize starch dust enters the space 14, at time t_1. Curves G,H and I have the same identities as in Figure 7. Figure 8 shows that both beams (at the two wavelengths) across the space 14 are affected by the dust and, more importantly, the output signal 40A (the signal produced by the near infra-red beam) is reduced by a greater extent than output signal 40B (produced by the blue light beam). The effect of this is that the ratio signal, R (curve I), is not reduced but in fact increases slightly.

Figure 9 corresponds to Figures 7 and 8 but shows the effects on curves G,H and I (identified as in Figures 7 and 8) in the presence of condensed water mist which, again, is introduced into the beam at time t_1. Again, Figure 9 shows that the water mist affects both output signals 40A and 40B but that the output signal 40A corresponding to the near infra-red beam is reduced to a greater extent than the output signal 40B corresponding to the blue beam. The ratio signal, R (curve C), is therefore not reduced, but in fact increases.

Figures 7,8 and 9 therefore show how detection and measurement of the ratio R enables the apparatus to distinguish between smoke on the one hand and "nuisance" aerosols on the other.

In all the forms of the apparatus described, the alarm level can therefore be set at a lower threshold than in conventional single beam detectors without increasing the likelihood of false alarms. The forms of apparatus shown in Figures 4,5 and 6 have the added advantage of automatic compensation for at least certain forms of contamination and source and detector drift.

Figure 7 shows that smoke attenuates blue light (corresponding to output signal 40B, curve H) more strongly than near infra-red light. Therefore, if the alarm threshold is set on the blue channel, there is an increase in sensitivity as compared with the sensitivity obtained by setting the threshold on the near infra-red channel.

CLAIMS

1. Particle detecting apparatus for detecting particles in suspension in a space and for distinguishing between particles of a first type and particles of a second type, comprising beam transmitting means for passing light at a plurality of different predetermined wavelengths through the space to detecting means operative to produce output signals respectively corresponding to the magnitude of the light received at the different wavelengths, the attenuation of the light caused by the presence of particles of the first type in the space being dependent on wavelength to a different extent from the attenuation of the light caused by the presence of particles of the second type in the space, whereby a comparison of the output signals from the detecting means enables detection of particles of the first type in preference to particles of the second type.

2. Apparatus according to claim 1, including reference means responsive to the light but unaffected by any said attenuation of the light, whereby to produce a corresponding correction signal dependent on the effect on the light of drift in the beam transmitting means, and means responsive to the correction signal for offsetting the effect of the drift on the said comparison of the output signals from the detecting means.

3. Apparatus according to claim 2, in which the reference means is responsive to the light before it is transmitted across the

space.

4. Apparatus according to any preceding claim, including ratio means connected to the detecting means for carrying out the said comparison by measuring the ratio of two of the output signals.

5. Apparatus according to any preceding claim, in which the beam transmitting means comprises means for transmitting the light in the form of a beam thereof at the plurality of wavelengths across the said space and in which the detecting means comprises a plurality of light detectors each responsive to light in a respective narrow band including a respective one of the wavelengths.

6. Apparatus according to claim 5, in which the detecting means includes beam splitting means for directing the beam to the respective detectors.

7. Apparatus according to claim 5 or 6, in which the beam transmitting means transmits substantially white light.

8. Apparatus according to any one of claims 1 to 4, in which the beam transmitting means comprises a plurality of separate transmitting means each for transmitting a beam across the said space in a narrow wavelength band including a respective one of the wavelengths, and in which the detecting means comprises detecting means responsive to the light in different

predetermined ones of the wavelengths to produce respective output signals.

9. Apparatus according to claim 8, including electrical processing means responsive to energisation of the separate transmitting means and to the output signals produced by the detecting means for separating the output signals.

10. Apparatus according to claim 9, in which the electrical processing means comprises means for energising the separate transmitting means at respectively different frequencies whereby the output signals have correspondingly different frequencies, and frequency discriminating means for separating the output signals in dependence on their frequencies.

11. Apparatus according to claim 9, in which the electrical processing means comprises means for energising the separate transmitting means at respectively different time instants whereby the corresponding output signals are produced at correspondingly different time instants.

12. Apparatus according to any one of claims 8 to 11 as dependent on claim 2 or 3, in which the reference means comprises means responsive to each said beam before it is transmitted across the said space and to produce corresponding reference output signals, and including means for comparing the reference output signals with each other to produce the correction signal

which is dependent on the effect on the beams of drift in the separate beam transmitting means.

13. Apparatus according to any one of claims 8 to 12, in which there are two separate transmitting means.

14. Apparatus according to any preceding claim, in which the attenuation of the light caused by the presence of particles of the first type in the space is dependent on wavelength to a greater extent than the attenuation of the beam caused by the presence therein of the particles of the second type, and in which the particles of the first type are smoke particles and the particles of the second type include dust and water mist.

15. Smoke detecting apparatus for detecting the presence of smoke in a space, comprising light transmitting means for transmitting light at at least a first and a second wavelength across the space to light detecting means, the light detecting means comprising first detecting means operative to detect variations in the magnitude of the light at the first wavelength to produce a first output signal and second detecting means operative to detect variations in the magnitude of the light received at the second wavelength so as to produce a second output signal, processing means operative to compare the two output signals, the first and second wavelengths being selected such that the effect of smoke in the space is to reduce one output signal substantially more than the other output signal and

such that this effect does not occur, or does not occur to the same extent, in response to the presence of non-smoke particles in the space, reference means responsive to the light before it is transmitted across the space to produce a corresponding correction signal dependent on the effect on the light of drift in the light transmitting means, and means responsive to the correction signal for offsetting the effect of the drift on the comparison of the output signals from the detecting means.

16. Apparatus according to claim 15, in which the processing means comprises means for measuring the ratio of the two output signals.

17. Apparatus according to claim 15 or 16, in which the reference means comprises means separately responsive to the light at the first and second wavelengths whereby the correction signal is dependent on the effect on the light at each wavelength of the said drift.

18. Apparatus according to any one of claims 15 to 17, in which the light detecting means comprises a light beam detector responsive to light at the first wavelength for producing the first output signal and a second light detector responsive to light at the second wavelength for producing the second output signal.

19. Apparatus according to claim 18, in which the light is

directed to the two light detectors via a beam splitter in the light detecting means.

20. Apparatus according to any one of claims 15 to 19, in which the light transmitting means comprises means for transmitting substantially white light across the space.

21. Apparatus according to claims 15 or 16, in which the light transmitting means comprises first and second transmitting means each for transmitting a light across the said space in a narrow wavelength band including a respective one of the first and second wavelengths, and in which the detecting means comprises detecting means responsive to light in both wavelenths to produce the said first and second output signals.

22. Apparatus according to claim 21, including electrical processing means responsive to energisation of the separate transmitting means and to the first and second output signals produced by the detecting means for separating the two output signals.

23. Apparatus according to claim 22, in which the electrical processing means comprises means for energising the first and second separate transmitting means at respectively different frequencies whereby the output signals have correspondingly different frequencies, and frequency discriminating means for separating the two output signals in dependence on their

frequencies.

24. Apparatus according to claim 22, in which the electrical processing means comprises means for energising the first and second separate transmitting means at respectively different time instants whereby the corresponding output signals are produced at correspondingly different time instants.

25. Apparatus according to any one of claims 21 to 24, in which the reference means comprises means responsive to the light at each said wavelength before it is transmitted across the said space to produce corresponding reference output signals, and means for comparing the reference output signals with each other to produce the correction signal which is dependent on the effect on the light of drift in the first and second transmitting means.

26. A method of detecting particles in suspension in a space and for distinguishing between particles of a first type and particles of a second type, comprising the steps of passing light at a plurality of predetermined wavelengths through the space, detecting the received light to produce output signals respectively corresponding to the magnitude of the light received at the different wavelengths, the attenuation of the light caused by the presence of particles of the first type in the space being dependent on wavelength to a different extent from the attenuation of the light caused by the presence of particles of the second type in the space, comparing the output signals to

enable detection of particles of the first type in preference to particles of the second type, detecting the light when it is unaffected by the said attenuation to produce a corresponding correction signal dependent on the effect of drift in the magnitude thereof, and using the correction signal to offset the effect of the drift on the comparison of the output signals.

27. A method according to claim 26, in which the step of carrying out the said comparison is carried out by measuring the ratio of two of the output signals.

28. A method according to claim 26 or 27, in which the transmitting step comprises transmitting a beam of light at a plurality of wavelengths across the said space, and the detecting step comprises detecting the received beam in a plurality of narrow bands each including a respective one of the wavelengths.

29. A method according to claim 28, in which the beam is transmitted in the form of substantially white light.

30. A method according to claim 26 or 27, in which the light transmitting step comprises the step of transmitting a plurality of beams across the said space each in a narrow wavelength band including a respective one of the wavelengths, and in which the detecting step comprises responding to the light in different ones of the wavelengths to produce the respective output signals.

31. Smoke detecting apparatus, substantially as described with reference to Figure 1 of the accompanying drawings.

32. Smoke detecting apparatus, substantially as described with reference to Figure 4 of the accompanying drawings.

33. Smoke detecting apparatus, substantially as described with reference to Figure 5 of the accompanying drawings.

34. Smoke detecting apparatus, substantially as described with reference to Figure 6 of the accompanying drawings.

35. A smoke detecting method, substantially as described with reference to Figure 1 of the accompanying drawings.

36. A smoke detecting method, substantially as described with reference to Figure 4 of the accompanying drawings.

37. A smoke detecting method substantially as described with reference to Figure 5 of the accompanying drawings.

38. A smoke detecting method, substantially as described with reference to Figure 6 of the accompanying drawings.

The Patent Office

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Application No:	GB 9724907.2	**Examiner:**	Bob Clark
Claims searched:	All	**Date of search:**	18 March 1998

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

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Other: Online: WPI

Documents considered to be relevant:

Category	Identity of document and relevant passage	Relevant to claims
Y	GB 2169401 A (HOCHIKI)	2,3,15,16, 18-22, 24, 26-30
X, Y	GB 1527965 A (ERICSSON) Whole document	X: 1, 4-9, 11, 13, 14 Y: 2,3,15, 16, 18-22, 24, 26-30
Y	US 4559453 (MUGGLI et al.)	2,3,15,16, 18-22, 24, 26-30
X, Y	US 3982130 (TRUMBLE) Whole document	X: 1,4,8, 9,11,13,14 Y: 2,3,15, 16, 20-22, 24, 26-30

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